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NATIONAL ADVISORY COMMITTEE

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No. 258

A W A R N I N G

CONCERNING THE TAKE-OFF WITH HEAVY LOAD

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Langley Memorial Aeronautical Laboratory

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A successful take-off can be made with an airplane so heavily loaded that it cannot climb to a height greater than the span of its wings.

The explanation is that the power required to maintain level flight at an altitude of the order of the wing span may be as much as 50 per cent greater than that necessary when the airplane is just clear of the ground.

The failure of heavily loaded airplanes to continue climbing at the rate attained immediately after the actual take-off is a grave hazard and has resulted in great risk or catastrophe in three notable cases which are cited.

Two years ago the writers of this note instituted and carried out an investigation of ground effect. The results of this work have been published only very recently in N.A.C.A. Technical Report No 265, "A Full Scale Investigation of Ground Effect." In this report it was pointed out that the climbing ability of an airplane is favorably affected by proximity to the ground and particularly so in the case of a heavily loaded

one. One of the most important conclusions to be drawn from this work is that an airplane can be taken off with a load greater than that which can be successfully carried across country.

At this time when so much interest is centered upon flights of long duration, transoceanic and otherwise, which are almost invariably attempted upon an airplane loaded practically to its capacity for getting off, the importance of this phase of ground effect should not be underestimated, because it must be borne in mind that after the airplane is free of the ground it must climb to a sufficient altitude to avoid obstacles of artificial or natural origin which may lie in its path and that often a change of direction is necessary shortly after the take-off.

Three cases in which the occurrence of this phenomenon has undoubtedly caused the endangering or loss of the lives of thoroughly capable pilots are of record:

1. Some time ago a very heavily loaded seaplane, which at that time was under test at our laboratory at Langley Field, was successfully taken off but could not be forced above an altitude of about 50 feet where level flight was maintained for approximately ten miles. A landing became obligatory at this point because the pilot considered it dangerous to make a turn under these conditions. Fortunately, this was successfully

accomplished and a portion of the load was removed in order that the return flight might be made.

2. The "American Legion" transoceanic airplane, piloted by the late Commander Davis and Lieutenant Wooster, taking off from Langley Field under full load conditions, left the ground after a run which was even somewhat shorter than had been expected, climbed with relative rapidity to an altitude of possibly 30 to 50 feet, and continued in the direction in which it had taken off until it was necessary to either rise or turn to avoid high trees. It is evident that the pilot chose the turn, whether or not he found it impossible to rise, which he made with only semi-success as accomplishment of the turn resulted in a disastrous loss of altitude.

3. According to press dispatches, Captain D'Oisy and M. Gonin left Le Bourget Field, France, for an objective in India but were unable to attain an altitude greater than 30 to 60 feet (conflicting reports) and were forced to land after having flown approximately $2\frac{1}{2}$ miles. Fortunately, both men escaped from the plane, which was entirely demolished as a result. Detailed technical advices in regard to this occurrence are not at hand as this is written two days following the accident.

Some intimate knowledge of the method of testing used by Commander Davis in preparation for his projected flight is at hand as are some less intimate but authentic data concerning

Colonel Lindbergh's preparations. In both cases the tests were directed almost entirely toward determination of the take-off characteristics under full load conditions. Particular attention was given to the length of ground run and the take-off speed, while less consideration was given to the more important factors, the rate of climb and the possibility of its continuation beyond the first few feet.

To explain the dilemma in which the pilot of a heavily loaded airplane may find himself immediately after take-off, it will probably be best to extract some information from the above-mentioned report on ground effect. Figure 1 illustrates the reduction of the power required for level flight as a conventional biplane (VE-7) approaches the ground. (The upper curve was obtained experimentally and the values for the lower one were calculated and confirmed by flight test; the middle curve was calculated in accordance with the method used for the lower one.) It will be seen that at an altitude of 500 ft. level flight may be maintained at the expense of approximately 33.5 HP. It is apparent, however, that when the airplane descends until its lower wing is approximately 7 ft. above the ground only 23.5 HP. are required to maintain level flight. A point of paramount interest will be noted in the minimum value of the power curve for an altitude of 15 ft. It will be seen at once that the greatest part of the reduction of power caused by ground effect takes place within a height equal to

about $1/2$ the span of the airplane. (Span of VE-7, 34.4 ft.)

The condition illustrated by these curves is characteristic of any conventional airplane. The reduction of the required power will be of approximately the same proportion for any normal airplane flying at comparable heights, the unit of comparison being taken as the span of the wings.

The operation of this phenomenon is best brought out by considering the conditions existing during the initial stages of the flight of the heavily loaded airplane. Let us suppose that such an airplane has gained flying speed and is at the point of leaving the ground. With the engine at full throttle the pilot finds that he gains altitude as rapidly as he would expect under the existing conditions. However, having reached a height approximately equal to the semi-span of the airplane, he notices that the rate of climb has decreased alarmingly. Slight changes of the attitude of the airplane are found to be of no avail. In the interim it is probable that he has passed the boundaries of the good landing surface of the airport and may then be confronted with the necessity of gaining still more altitude in order to avoid some obstacle. Finding this impossible, he can only choose between collision with the obstacle and the doubtful alternative of attempting a turn. In either case a serious accident is probable if not inevitable.

Figure 2 is an illustration of a hypothetical case. It will be seen that the airplane begins to climb at a reasonable

initial rate. The dashed curve shows what the pilot might expect of the airplane if the effect of ground interference caused only a negligible reduction of the excess power available for climbing, as is the case with normal loads. In this case, however, the excess power is a small portion of the total power available and is quickly absorbed in overcoming the added resistance which accompanies the gain of altitude. This results in fixing the absolute ceiling of the airplane at a very small distance above the ground. The solid curve then indicates the actual performance of the airplane. This figure is added to bring out the nature of the danger in more graphic form.

To avoid getting into this dangerous condition when an airplane is taking off with an unusually heavy load, a careful study of the rates of climb with smaller loads should be made. It is to be expected that the curve of rate of climb vs. load will reach a zero rate for a load considerably smaller than that which can be taken off at attainable speeds and within lengths of ground run possible on existing airports.

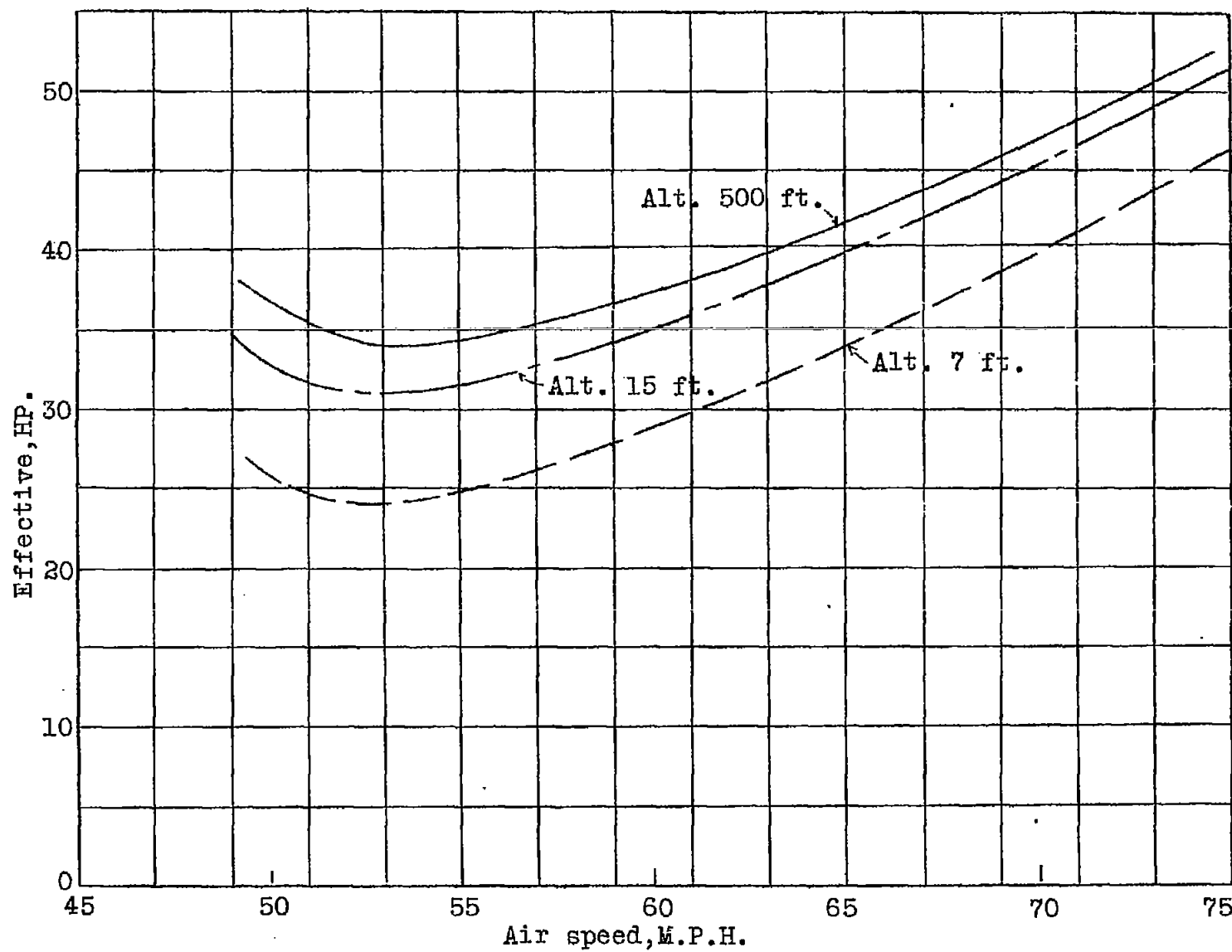


Fig. 1

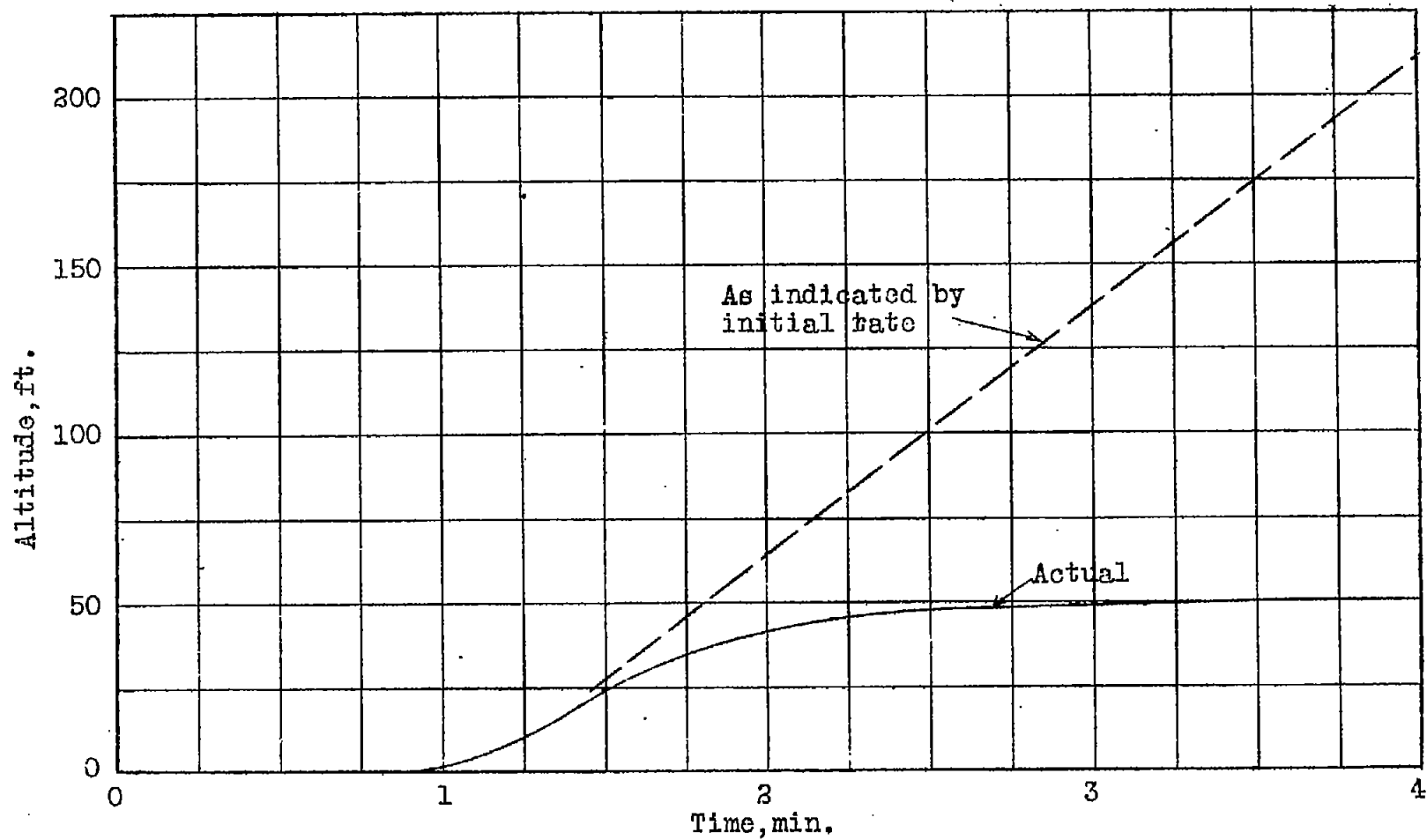


Fig. 2